PHYSICS AND CHEMISTRY

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PHYSICS AND CHEMISTRY

FOR SECONDARY SCHOOLS IN INDIA

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CONTENTS.

NOTE.—The experiments marked (*) and the experiments marked (**) should be omitted during the first reading, but should be performed (especially the latter) if possible, during revision at the end of the year.

PART II.

CHAPTER I.

THERMOMETERS.

CHAPTER II.

AREA.

CHAPTER III.

VOLUME.

CHAPTER IV.

HEAT.

CHAPTER V.

HYDROSTATICS.

CHAPTER VI.

CHEMISTRY.

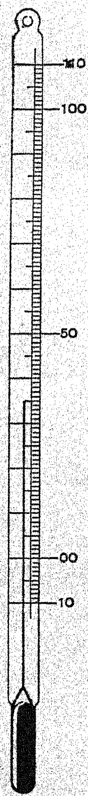
CHAPTER I.

THERMOMETERS.

IN Part I. you learnt about the *Centigrade Thermometer*. There is another form of thermometer, called the **Fahrenheit Thermometer**, which is often used in engineering. The fixed points are found in the same way as for the Centigrade Thermometer (by placing the bulb in melting ice and in steam), and are marked 32 degrees Fahrenheit (32° F.) and 212 degrees Fahrenheit (212° F.) respectively. The distance between the points is divided into 180 equal parts. Fig. 1 shows a Centigrade Thermometer, and Fig. 2 a Fahrenheit Thermometer. If you were to place these two thermometers in melting ice, the mercury in the Centigrade Thermometer would stand at the mark 0° C., and the mercury in the Fahrenheit Thermometer would stand at 32° F.; if you were to place both thermometers in the steam of boiling water, the mercury in the Centigrade Thermometer would stand at 100° C., and the mercury in the Fahrenheit Thermometer at 212° F. Hence between the Freezing Point and the Boiling Point on a Centigrade Thermometer there are 100 divisions, but between the Freezing Point and the Boiling Point on a Fahrenheit Thermometer there are 180 divisions. Therefore

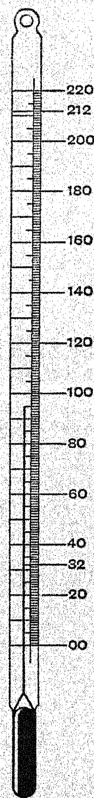
100 divisions C. = 180 divisions F.

or **5 divisions C. = 9 divisions F.**



Centigrade Thermometer

FIG. 1.



Fahrenheit Thermometer

FIG. 2.

To obtain the reading on a Fahrenheit Thermometer corresponding to a given reading on a Centigrade Thermometer.

EXAMPLE 1.—*What is the reading on a Fahrenheit Thermometer corresponding to 86·4° C.?*

86·4° C. is 86·4° C. *above Freezing Point.*

But $\quad$ 5 divisions C. = 9 divisions F.

Hence $\quad$ 1 division C. = $\frac{9}{5}$ division F.

Therefore $86{\cdot}4^\circ$ C. = $\frac{9}{5}(86{\cdot}4)^\circ$ F. *above Freezing Point,*

or $\quad 86{\cdot}4^\circ$ C. = $155{\cdot}5^\circ$ F. + 32° F.

$= 187{\cdot}5^\circ$ F.

EXAMPLE 2.—*What is the reading on a Fahrenheit Thermometer corresponding to x° C., where x is any reading on the Centigrade Thermometer?*

x° C. is x° C. *above Freezing Point.*

But $\quad$ 5 divisions C. = 9 divisions F.

Hence $\quad$ 1 division C. = $\frac{9}{5}$ division F.

Therefore x° C. = $\frac{9}{5}x^\circ$ F. *above Freezing Point,*

or $\quad x^\circ$ C. = $\frac{9}{5}x^\circ$ F. + 32° F.,

x° C. = $(\frac{9}{5}x + 32)^\circ$ F.

The last result is a *formula* which we may use to calculate for any reading on the Centigrade Thermometer the corresponding reading on the Fahrenheit Thermometer.

EXAMPLE 3.—Calculate the readings on a Fahrenheit Thermometer corresponding to

(i) $60{\cdot}3^\circ$ C., (ii) $12{\cdot}5^\circ$ C., (iii) -3° C.

Using the formula, x° C. = $(\frac{9}{5}x + 32)^\circ$ F.:

(i) $60{\cdot}3^\circ$ C. = $(\frac{9}{5} \times 60{\cdot}3 + 32)^\circ$ F. = $(108{\cdot}5 + 32)^\circ$ F = $140{\cdot}5^\circ$ F.

(ii) $12{\cdot}5^\circ$ C. = $(\frac{9}{5} \times 12{\cdot}5 + 32)^\circ$ F. = $54{\cdot}5^\circ$ F.

(iii) -3° C. = $(\frac{9}{5} \times -3 + 32)^\circ$ F. = $(-5{\cdot}4 + 32)^\circ$ F. = $26{\cdot}6^\circ$ F.

To obtain the reading on a Centigrade Thermometer corresponding to a given reading on a Fahrenheit Thermometer.

EXAMPLE 1.—*What is the reading on a Centigrade Thermometer corresponding to* $164{\cdot}3^\circ$ *F.?*

$164{\cdot}3^\circ$ F. = $164{\cdot}3^\circ$ F. *above Zero*

$= (164{\cdot}3 - 32)^\circ$ F. *above Freezing Point*

$= 132{\cdot}3^\circ$ F. above Freezing Point

But 9 divisions F. = 5 divisions C.
Therefore 1 division F. = $\frac{5}{9}$ division C.
Hence $164 \cdot 3^\circ$ F. = $\frac{5}{9} \times 132 \cdot 3^\circ$ C. *above Freezing Point*

$$= \tfrac{5}{9} \times 132 \cdot 3^\circ \text{ C.}$$
$$= 73 \cdot 5^\circ \text{ C.}$$

EXAMPLE 2.—*Prove* the following formula :

$$x^\circ \text{ F.} = \tfrac{5}{9}(x - 32)^\circ \text{ C.}$$

EXAMPLE 3.—Calculate the readings on the Centigrade scale corresponding to

(i) $178 \cdot 4^\circ$ F., (ii) 79° F., (iii) $18 \cdot 2^\circ$ F.

Using the formula, x° F. = $\frac{5}{9}(x - 32)^\circ$ C. :—

$$\text{(i) } 178 \cdot 4^\circ \text{ F.} = \tfrac{5}{9}(178 \cdot 4 - 32)^\circ \text{ C.}$$
$$= \tfrac{5}{9} \times 146 \cdot 4^\circ \text{ C.}$$
$$= 81 \cdot 3^\circ \text{ C.}$$
$$\text{(ii) } 79^\circ \text{ F.} = \tfrac{5}{9}(79 - 32)^\circ \text{ C.}$$
$$= \tfrac{5}{9} \times 47^\circ \text{ C.}$$
$$= 26 \cdot 1^\circ \text{ C.}$$
$$\text{(iii) } 18 \cdot 2^\circ \text{ F.} = \tfrac{5}{9}(18 \cdot 2 - 32)^\circ \text{ C.}$$
$$= \tfrac{5}{9} \times -13 \cdot 8^\circ \text{ C.}$$
$$= -7 \cdot 7^\circ \text{ C.}$$

EXERCISE 1.

1. Express in the Fahrenheit scale the following Centigrade readings :

$97 \cdot 6^\circ$ C., 83° C., 15° C., -5° C.

2. On the Fahrenheit scale the temperatures of several bodies are : 71° F., 68° F., 0° F., -40° F. What would be the corresponding readings on a Centigrade Thermometer ?

3. The boiling points of the following liquids were read on the Fahrenheit scale; what are they in Centigrade readings ?

Ether - - - - -	95° F.
Glycerine - - - -	554° F.
Mercury - - - -	674·6° F.
Sulphuric acid - - -	640·4° F.
Benzine - - -	176° F.

4. Convert the following melting points to the corresponding Fahrenheit readings :

Brass - - - - -	1000° C.
Gold - - - - -	1067° C.
Cast iron - - - -	1200° C.
Tin - - - - -	230° C.
Zinc - - - - -	415° C.

EXPERIMENT 1.—To compare the readings on a Centigrade and a Fahrenheit Thermometer.

1. About half fill a beaker with water. Place the beaker on a tripod stand, and heat it until the water begins to boil. Place a Centigrade and a Fahrenheit Thermometer in the water ; take away the flame and let the water cool. Stir the water with the thermometers. Read them at the same time at intervals of a few minutes, and record the readings in a table as follows :

Reading of Centigrade Thermometer.	Corresponding Reading of Fahrenheit Thermometer.
° C.	° F.

Precautions :

(1) Do not remove the bulb from the water while taking the reading.

(2) While taking a reading place the eye directly opposite the part at which the mercury stands.

(3) Read to fifths of a degree.

2. Plot a graph to show the relationship between the corresponding readings of the two thermometers. If you do not know how to plot a graph, proceed as in the following experiment.

EXPERIMENT 2.—To plot a graph to show the connection between the Centigrade and Fahrenheit scales of temperature.

The following results were obtained in an experiment :

Readings on the Centigrade Scale.	20	34	46	52	64	70	86	90
Corresponding Readings on the Fahrenheit Scale.	68	93·4	118	125·2	147·2	154	186 6	194

To "plot a graph" means to draw a line to represent the relationship between two quantities ; in this experiment we wish to represent the relationship between the readings of a Centigrade Thermometer and the readings of a Fahrenheit Thermometer.

Draw two lines (Fig. 3) OX and OY at right angles on squared paper. Distances parallel to OX are to represent readings on the Centigrade scale ; these distances are called *abscissae* (singular *abscissa*). Distances parallel to OY are to represent readings on the Fahrenheit scale ; these distances are called *ordinates*.

Divide OX into equal parts, each part representing a certain number of degrees Centigrade, choosing as large a scale as is convenient. Since, in this experiment, the readings of the Centigrade Thermometer range from 20° to 90°, and along OX there are 60 small divisions, we therefore take 10 small divisions to represent 20° C. The

readings on the Fahrenheit Thermometer range from 68° to 194°, and along OY there are 80 small divisions; we

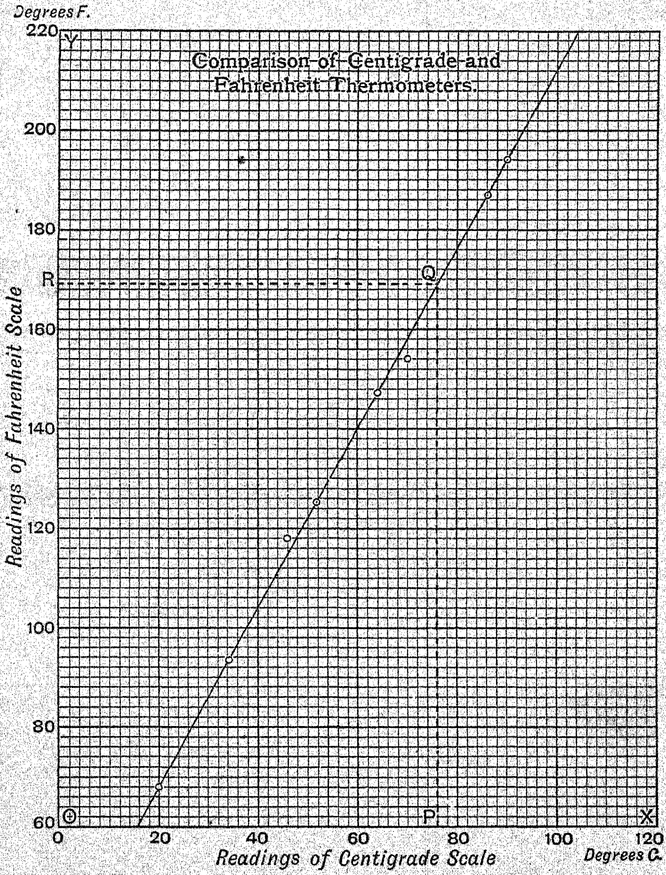


FIG. 3.

therefore take 10 small divisions to represent 20° F. Number the line OX, and put the units, "degrees C.," at the end; similarly number the line OY and put the

units, "degrees F.," at the end. Name the lines; "Readings of Centigrade Scale" being written along one line, and "Readings of Fahrenheit Scale" along the other.

When the reading on the Centigrade scale is 20°, the Fahrenheit scale reads 68°; therefore go along OX until you come to the point 20 (10 small divisions from the corner) and up a vertical line until you reach 68 (4 small divisions from OX), and make a dot at the point found.

Repeat for each of the pairs of values given in the table.

Draw a smooth line to pass as nearly as possible through all the dots. If the line cannot be drawn through all the dots, it should be drawn as nearly as possible between them. If it passes through most of the dots, while one or two dots are at some distance from it, this will mean that errors in measurement have been made, and the results represented by the dots which are not on the line should be neglected. If the form of the line appears to be a straight line, a ruler may be used to draw it. When the line has been drawn, draw a small circle round the dots to show what points represent results found by experiment.

The graph should be named at the top of the paper.

We can use this graph to find the reading on one scale corresponding to the reading on the other. Thus, to find the reading on the Fahrenheit scale corresponding to 76° C. Find the point P on OX representing 76° C. Go vertically up from this point P until you meet the graph at Q; then go horizontally along until you meet the line OY at R. The point R represents 169·2° F., which is therefore, according to the experiment, the reading on the Fahrenheit scale corresponding to 76° C.

EXPERIMENT 3.—To draw the cooling curve for water.

About half fill a beaker with water. Place the beaker on a tripod stand, and heat it until the water begins to

boil. Take away the flame, and let the water cool. Start estimating time from the instant at which the thermometer stands at 90°, and find how long the water takes to cool to the other temperatures given in the following table:

Fall in Temperature.	Time of Cooling.
° C.	Seconds.
90° to 80°	
,, ,, 70°	
,, ,, 65°	
,, ,, 60°	
,, ,, 55°	
,, ,, 50°	
,, ,, 45°	
,, ,, 40°	

Plot a graph to show the relationship between the temperature and the time taken to fall from 90°. This graph will not be a straight line like the graph in Experiment 2; you will, therefore, have to draw it freehand; it is called the *cooling curve for water*.

EXERCISE.

From this graph find the time taken by the water to cool from 90° C. to 75° C., and from 68° C. to 48° C.

CHAPTER II.

AREA.

Area by Weighing.—In Part I. you learnt how to find the area of figures by drawing them on squared paper. The method of finding area used in the following experiment is very accurate. It can be used to find the area of any regular or irregular figure of uniform thickness.

EXPERIMENT 4.—To find the area of a circle by weighing.

Find the area of the given rectangular card by measurement and calculation. Weigh the card. Divide the weight by the area to get the weight of 1 sq. cm. of the card. Draw on the card a circle of 16 cm. diameter. Cut out the circle. Weigh the circle. Divide the weight of the circle by the weight of 1 sq. cm. of the card. This will give the area of the circle in sq. cm.

Repeat for circles of 12 cm., 10 cm., and 8 cm. diameter.

Enter the results thus :

Weight of card - - = gm.
Area of card - - - = sq. cm.
Weight of 1 sq. cm. of card = gm.

Radius of Circle.	Weight of Circle.	Area of Circle.
cm.	gm.	sq. cm.
8		
6		
5		
4		

FORMULA FOR THE AREA OF A CIRCLE.

Divide the area of each of the circles used in Experiment 4 by the square of its radius. Enter results in a table as follows:

Radius of Circle.	Area of Circle (from Expt. 4).	$\frac{\text{Area of Circle}}{(\text{radius})^2}$.
cm.	sq. cm.	

If the experiment was done accurately, the results in the last column should all be the same, namely 3·14, the constant which you know is π.

If we call A the area of the circle, and r the length of the radius, then we have

$$\frac{A}{r^2}=\pi,$$

or $A=\pi r^2$, which is a *formula for finding the area of a circle.*

EXAMPLE.—Find the area of a circle whose diameter is 17·8 cm.

$$A=\pi r^2,$$

where A is the area of the circle, r is the length of the radius and $\pi=3{\cdot}14$.

$$\therefore\ A=3{\cdot}14\times(8{\cdot}9)^2 \text{ sq. cm.}$$
$$=248{\cdot}7 \text{ sq. cm.}$$

EXERCISE 2.

1. What is the area of a circle whose diameter is 77·5 mm.?

2. How many holes 3 mm. in diameter will have an area equal to that of a pipe 6 cm. in diameter?

3. Which will carry more water:

(*a*) One pipe 6 in. internal diameter,

or (*b*) Two pipes each of 3 in. internal diameter?

4. A circular plot of grass, of which the diameter is 125 ft., is surrounded on the outside by a gravel path $7\frac{1}{2}$ ft. wide. Find the area of the path in sq. yards.

5. Plot a graph to represent the results of Experiment 4, and from your graph find the areas of circles whose radii are 7·2 cm., 5·5 cm., and 4·8 cm. Verify your results by calculation.

ADDITIONAL EXPERIMENTS.

EXPERIMENT 5.*—To verify the formula for the area of a circle by means of squared paper.

Describe on squared paper a circle of 8 cm. radius. Find its area in sq. cm. by counting the number of mm. squares and dividing by 100. Divide the area of the circle by the square of the radius.

Repeat for circles of various sizes, and find the average of your results.

EXPERIMENT 6.*—To find the area of an irregular piece of tin.

You are supplied with an irregular piece of tin sheet, and a rectangle made of the same material. Weigh the rectangle. By measurement and calculation find its area. From your results calculate the weight of 1 sq. cm. of the tin. Weigh the given irregular piece, and divide its weight by the weight of 1 sq. cm. of tin; this will give you the area.

CHAPTER III.

VOLUME.

EXPERIMENT 7.—To find the volume of a cylinder by displacement.**

You are given a metal cylinder. Select a measuring cylinder into which the metal cylinder will just pass, and about half fill the measuring cylinder with water. Take the reading of the surface of the water. Tie a thin cotton thread to the metal cylinder, and gently lower it into the measuring cylinder until it is completely immersed. Again take the reading of the surface of the water. The difference between the two readings gives the volume of the metal cylinder.

Enter results thus :

Second reading of measuring cylinder =		c.c.
First ,, ,, ,, =		c.c.
Difference = Volume of metal cylinder =		c.c.

Repeat the experiment three times, and take the average of the results.

The following is a more accurate method for finding the volume of the cylinder :

EXPERIMENT 8.*—To find the volume of a cylinder by weighing.

You are given a cylinder and a rectangular solid made of the same metal. Weigh the rectangular solid. Find its

volume by measurement and calculation. In case this solid has not been made quite accurately, multiply the *average* height, the *average* length, and the *average* breadth together. Divide the weight of the rectangular solid by its volume to get the weight of 1 c.c. of the material.

Weigh the cylinder. Find the volume of the cylinder by dividing its weight by the weight of 1 c.c. of the material.

Enter results thus:

Weight of rectangular solid			=	gm.
Average height of rectangular solid			=	cm.
,, length	,,	,,	=	cm.
,, breadth	,,	,,	=	cm.
Volume	,,	,,	=	c.c.

$$\text{Weight of 1 c.c. of the material} = \frac{\text{weight of rectangular solid}}{\text{volume of rectangular solid}} = \quad \text{gm.}$$

Weight of cylinder = gm.

$$\text{Volume of cylinder} = \frac{\text{weight of cylinder}}{\text{weight of 1 c.c. of the material}} = \quad \text{c.c}$$

FORMULA FOR THE VOLUME OF A CYLINDER.

You know that the volume of a rectangular solid is found by multiplying the area of the base by the height. The volume of a cylinder is found in the same way. The area of the base of a cylinder is $\pi \times r^2$, where $\pi = 3{\cdot}14$ and r is the length of the radius. Hence the volume of a cylinder is $h \times \pi r^2$, where h is its height.

If we call V the volume of the cylinder, we have the formula:

$$V = h \times \pi r^2.$$

EXPERIMENT 9.—To find by measurement and calculation the volume of a cylinder.**

Take the cylinder used in Experiment 8. Measure its height by means of a rule; in doing this measure at three different places, and find the average. Measure the

diameter of the cylinder by means of the callipers; take measurements at three different places, and find the average. Then use the formula $V = h \times \pi r^2$ to find the volume of the cylinder. Compare your result with what you found by Experiment 7 or Experiment 8.

Enter results thus:

h = average height of cylinder	=	cm.
$r = \frac{1}{2}$(average diameter of cylinder)	=	cm.
Volume of cylinder $= h \times \pi r^2$	=	c.c.
Volume of cylinder (by experiment)	=	c.c.

EXAMPLE.—Find the volume of a cylinder whose height is 8·4 cm., and whose diameter is 5 cm.

$$V = h \times \pi r^2,$$

where V = volume of cylinder; h = height of cylinder; r = radius of cylinder.

Hence $V = 8{\cdot}4 \times 3{\cdot}14 \times (2{\cdot}5)^2$ c.c.
$= 164{\cdot}8$ c.c.

EXERCISE 3.

1. Find the volume of a metal cylinder whose height is 20 cm., and whose diameter is 12 cm.

2. What is the capacity of a glass cylinder whose inside measurements are :—height = 8 cm., diameter = 78 mm. ?

3. Which will hold more water :—
   (a) One pipe of 10 in. diameter and 24 in high,
   or (b) Two pipes of 5 in. diameter and 48 in. high ?

4. The length of a lead pipe is 50 cm. Its external diameter is 1·5 cm., and its internal diameter is 1·2 cm. How many c.c of lead are there in the pipe ?

5. A hollow metal cylinder is 24 cm. high and 12 cm. in external diameter. If the metal is 3 mm. thick, what is the volume of metal in the cylinder ?

6. The internal diameter of a burette is 1·6 cm. How far will the graduations 0—50 c.c. extend along the burette ?

7. What must be the least depth (inside) of a uniform graduated cylinder made to hold 500 c.c., if its internal diameter is 5 cm. ?

EXPERIMENT 10.*—To compare the volumes of a cone and sphere with that of the corresponding cylinder (by use of burette).

You are given a hollow cylinder, a hollow cone (both made of tin), and a sphere. The heights of the cone, sphere, and

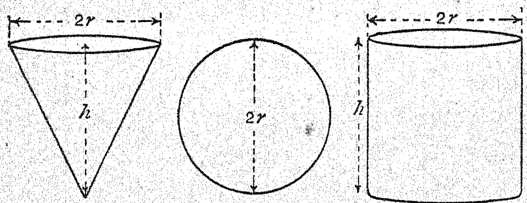


FIG. 4.

cylinder are the same ; the sphere just fits inside the cylinder, and the diameter of the cylinder is equal to the diameter of the inside of the base of the cone (Fig. 4).

Measure by the burette the amount of water required just to fill the cylinder. Pour the water out and place the sphere inside the cylinder. Find the amount of water required to fill the cylinder with the sphere inside it, and by subtraction find the volume of the sphere. (If the sphere is a wooden one keep it immersed by means of a pin.) Find the volume of the cone by the burette.

(i) Divide the volume of the sphere by the volume of the cylinder.

(ii) Divide the volume of the cone by the volume of the cylinder.

Enter your results thus :

Volume of cylinder - - - - -	=	c.c.
Volume of cylinder (with sphere inside)	=	c.c.
Volume of sphere - - - - -	=	c.c.
Volume of cone - - - - -	=	c.c.

(i) $\frac{\text{Volume of sphere}}{\text{Volume of cylinder}} =$. (ii) $\frac{\text{Volume of cone}}{\text{Volume of cylinder}} =$

If you perform the experiment accurately you should get the fraction $\frac{2}{3}$ as the answer to (i), and the fraction $\frac{1}{3}$ as the answer to (ii).

The following is a more accurate method of comparing these volumes.

EXPERIMENT 11.*—To compare the volumes of a cone and a sphere with that of the corresponding cylinder (by weighing).

You are given a cone, a sphere, a cylinder, and a rectangular solid,—all made of the same material. The heights of the cone, sphere, and cylinder are the same, and the diameter of the sphere is equal to the diameter of the cylinder and of the base of the cone. Weigh the rectangular solid. Find its volume by multiplying together its *average* height, its *average* length, and *average* breadth.

Divide the weight of the rectangular solid by its volume to get the weight of 1 c.c. of the material. Weigh the sphere, the cone, and the cylinder. Find the volume in each case by dividing the weight of the solid by the weight of 1 c.c. of the material.

(i) Divide the volume of the sphere by the volume of the cylinder.

(ii) Divide the volume of the cone by the volume of the cylinder.

Enter results thus :

Weight of rectangular solid - -	=	gm.
Average height of rectangular solid	=	cm.
,, length ,, ,,	=	cm.
,, breadth ,, ,,	=	cm.
Volume of rectangular solid - -	=	c.c.

Weight of 1 c.c. of the material $= \dfrac{\text{weight of rectangular solid}}{\text{volume of rectangular solid}} =$ gm.

Name of Solid.	Weight of Solid.	Volume of Solid.
	gm.	c.c.
Cone - -		
Sphere -		
Cylinder -		

(i) $\dfrac{\text{Volume of sphere}}{\text{Volume of cylinder}} =$. (ii) $\dfrac{\text{Volume of cone}}{\text{Volume of cylinder}} =$.

FORMULAE FOR VOLUMES OF SPHERE AND CYLINDER.

If Experiments 10 and 11 had been done accurately you would have found the following results :

(i) $\dfrac{\text{Volume of sphere}}{\text{Volume of cylinder}} = \frac{2}{3}$ and (ii) $\dfrac{\text{Volume of cone}}{\text{Volume of cylinder}} = \frac{1}{3}$.

The sphere, cone, and cylinder were all of the same height.

Let h be this height.

The radius of the sphere is equal to the radius of the cylinder and of the base of the cone ; let r be the length of this radius.

From (i),

$$\textbf{Volume of sphere} = \tfrac{2}{3} \times \text{volume of cylinder}$$
$$= \tfrac{2}{3} \times h \times \pi r^2$$
$$= \tfrac{4}{3}\pi r^3 \text{ (since } h = 2r\text{)}.$$

From (ii),

Volume of cone $= \frac{1}{3} \times$ volume of cylinder
$= \frac{1}{3} \times h \times \pi r^2.$

Hence, if r is the radius of a sphere,

$$\textbf{Volume of sphere} = \tfrac{4}{3}\pi r^3.$$

And, if h is the height of a cone, and r is the radius of its base :

$$\textbf{Volume of cone} = \tfrac{1}{3} \times h \times \pi r^2.$$

EXAMPLES.

1. Find the volume of a sphere whose diameter is 4 cm.

$$\text{Volume of sphere} = \tfrac{4}{3}\pi . r^3,$$

where r is the radius of the sphere.

Hence, volume of sphere $= \frac{4}{3} \times \pi \times (2)^3$ c.c.
$= 33{\cdot}5$ c.c.

2. The height of a cone is 14 cm., and the radius of its base is 5 cm. ; find its volume.

Volume of cone $= \frac{1}{3} \times h \times \pi r^2$,
where h = height of the cone,
r = radius of its base.

Hence,

Volume of cone $= \frac{1}{3} \times 14 \times 3{\cdot}14 \times 5^2$ c.c.
$= 366{\cdot}4$ c.c.

EXERCISE 4.

1. A sphere just slips into a cubical box, one edge of which measures 5 cm. How much space is left unoccupied ?

2. The vertical height of a conical roof is 10 ft., and the diameter of the base is 6 ft. What is the volume within the conical portion ?

3. A spherical tower 12 ft. in diameter has a conical top. If the total height of the tower is 80 ft., and the conical portion is 15 ft. high, what is the volume of the tower ?

4. What is the volume of a tent of diameter 15 ft. and height 10 ft., if the tent forms a cone?

5. Find the volume of a football of 11 in. outside diameter. If the leather is $\frac{1}{8}$ in. thick, what is the volume of the leather?

6. How many cu. ft. of gas will it take to inflate a balloon whose diameter when full is 36 ft.?

7. How many balls of 1·4 in. diameter will weigh the same as one of 1 ft. diameter, and made of the same material?

ADDITIONAL EXPERIMENTS.

EXPERIMENT 12.*—To find the internal diameter of a narrow glass tube.

Cork one end of the given glass tube. Run in a little water from a burette. Mark the level of the water in the glass tube, and take the reading of the burette.

Run in several c.c. of water and again mark the level in the glass tube. Take the second reading of the burette.

Measure the distance between the two marks. Find out how much water it took to fill that length.

Divide the volume by the length to find the area of the cross-section of the tube.

From your results calculate the diameter of the glass tube.

EXPERIMENT 13.*—To find the volume of a triangular prism.

You are provided with a small triangular prism. You know that the volume of a rectangular solid is found by multiplying the height by the area of the base. The volume of a triangular prism is found in the same way, namely, by multiplying the height by the area of the base. Assuming that this is true, calculate the volume of the triangular prism.

Test your result by finding the volume of the prism by the method of displacement of water.

EXPERIMENT 14.*—To find the volume of a pyramid.

The volume of a pyramid is calculated from the formula,

$$\text{Volume of pyramid} = \tfrac{1}{3} \text{ area of base} \times \text{height}.$$

Take the necessary measurements and calculate the volume of the pyramid provided, and test your result by finding the volume by displacement of water.

CHAPTER IV.

HEAT.

EXPERIMENT 15.—Melting of ice.

About half fill a large test-tube with small pieces of dry ice, and insert a thermometer into them. Place the test-tube in a beaker of cold water. Warm the beaker by a small flame, and read the thermometer at intervals, keeping the ice stirred with the thermometer. Notice that so long as any of the ice remains unmelted the temperature does not rise above the melting point (0° C. or 32° F.).

MELTING POINT OF SOLIDS.

Many other substances behave in the same way as ice. Below a certain temperature they are solids, but when heated to this temperature they melt. This temperature is called the *melting point of the solid*; so long as any of the solid remains unmelted its temperature does not rise above the melting point.

EXPERIMENT 16.—To find the melting point of paraffin wax, and sulphur.

(i) Take a piece of glass tubing and heat it in the middle until it is quite soft; remove it from the flame and draw the two ends apart. You will thus have a long thin tube.

From this tube cut off a piece about 3 in. long and $\frac{1}{10}$ in. wide. Seal up the narrower end of the tube. Cut up some paraffin wax into very small pieces and shake a little to the bottom of the tube. By means of a piece of thread fasten the tube to the thermometer so that the paraffin is

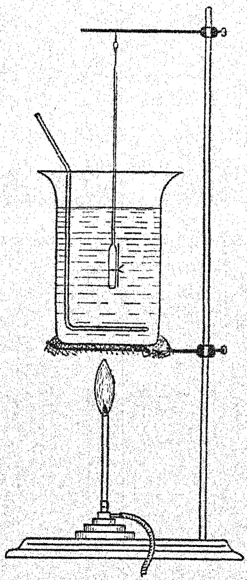


FIG. 5.

opposite the middle of the bulb. Support the thermometer and tube in a beaker of cold water as shown in Fig. 5. See that the bulb and tube dip well below the surface of the water. Heat the water *slowly*, continually stirring it; the best form of "stirrer" is a piece of stout wire bent at one end into a circle, and at the other end to form a handle. As soon as the paraffin wax *begins* to melt, note the temperature and immediately remove the flame. As soon as the wax has become solid, again warm the beaker, and again

find the temperature at which the wax begins to melt. This second reading will probably be made more accurately than the first, and may be taken as *the melting point of paraffin wax.* Repeat the experiment three times, and find the average of your results.

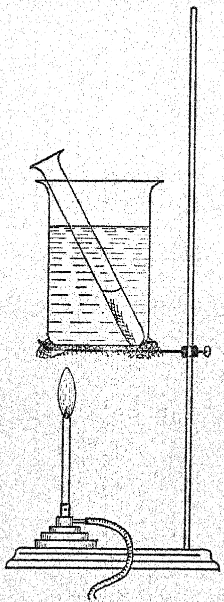


FIG. 6.

(ii)* In the same way find the melting point of sulphur. As the melting point of sulphur is higher than the boiling point of water, you will have to use glycerine instead of water, and a thermometer which can register up to a temperature of at least 140° C.

The following is another method for finding the melting point of a solid.

EXPERIMENT 17.—To find the melting point of naphthalene.

You found that when a thermometer was placed in melting ice it gave a constant reading. A similar result will be found for any solid; the temperature of any substance remains constant while it is passing from the solid to the liquid state, or from the liquid to the solid state.

Place some naphthalene in a test-tube so as to fill it about three-quarters full. Place the tube in a beaker of water and heat the beaker until the naphthalene is all melted (Fig. 6). When the naphthalene begins to melt place a thermometer in the test-tube (keeping the test-tube in the water), and heat the water until the temperature of the naphthalene is over 80°. Take the test-tube out of the water and, holding it in the air, stir the liquid gently with a thermometer. Read the temperature every 15 seconds, and record the readings in a table as follows:

Time in intervals of 15 seconds.	Temperature of cooling naphthalene.
	°C.

Your partner should be ready with his watch when you take the test-tube out of the water, and he should tap on the table at intervals of 15 seconds. When he taps you will call out the reading, and he will write it down. The readings should be continued for some minutes after the wax has solidified.

Plot a graph between time and temperature, taking time as abscissae and temperatures as ordinates. The graph will

be of the form shown in Fig. 7. The portion AB corresponds to the interval during which the temperature remained

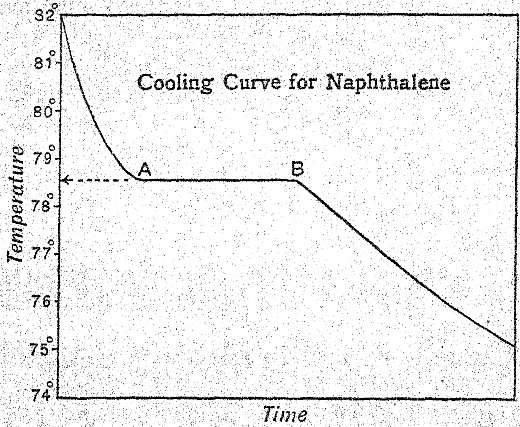


FIG. 7.

constant. This temperature is *the melting point of naphthalene*, and is found by producing the horizontal portion of the graph to meet the axis of temperatures.

CONVEYANCE OF HEAT BY SOLIDS, LIQUIDS, AND GASES.

CONDUCTION.

When solids are heated the heat slowly passes along the substance from particle to particle. This conveyance of heat is called **conduction of heat.**

EXPERIMENT 18.—To show that some solids conduct heat more quickly than others.

(i) You are given similar rods of copper and iron. Fasten marbles by wax to the rods in corresponding positions (Fig. 8). Fix the rods in two retort stands at the same level. Place the retort stands so that the ends of the rods are in

contact. Place the flame of the burner under the rods, so that they are equally heated. You will notice that the marbles drop off from the copper rod much sooner than from the iron rod. This proves that heat travels more quickly along the copper rod than along the iron rod; copper is said to be a *better conductor of heat* than iron.

Repeat the experiment, using glass and iron rods, and so prove that iron is a better conductor of heat than glass.

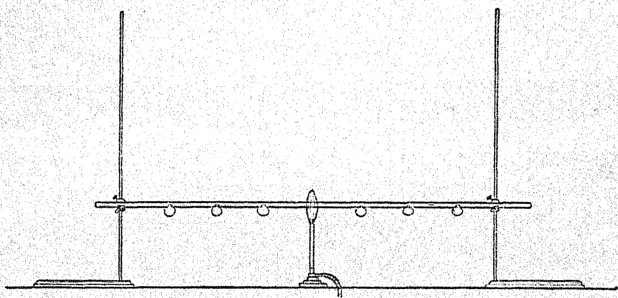


FIG. 8.

(ii) You are given an apparatus consisting of a piece of wood with a piece of sheet brass let into it. Paste paper over the wood and brass. Heat gently in the flame. Notice that the paper covering the wood is charred, while that covering the brass is not. The reason is that the brass conducts the heat away so quickly from the paper that the latter is not burnt, but wood does not conduct heat quickly, and so the paper covering the wood becomes charred.

NOTE.—Experiments 18, 19, 20, 21, 22 may be done at the lecture table by the teacher.

CONVECTION.

EXPERIMENT 19.—To show how heat is conveyed in a liquid.

Fill a beaker with cold water. Drop into the beaker a small piece of potassium permanganate so that it lies at

the side of the beaker. Heat the beaker by a small flame at the point at which the solid lies (Fig. 9). Notice how the red liquid travels. The water immediately over the flame becomes heated, expands, and, being thus bulk for bulk lighter than the rest of the water, rises to the top, and the cold denser water sinks to take its place. This in its turn

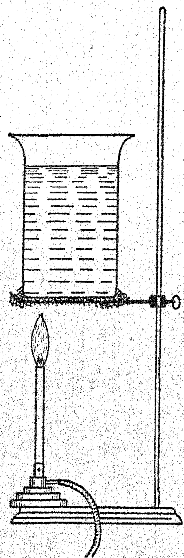


FIG. 9.

is heated, and rises to the top. Thus, when a liquid is heated it circulates in currents. These currents are called **convection currents.** They carry the heat with them and heat the rest of the liquid. Liquids heated in this way are said to be heated by **convection.** If a gas is heated, heat is conveyed through it by convection currents as in liquids. Convection currents are made use of in the ventilation of buildings.

RADIATION.

If you place your hand in front of a flame you *instantly* feel the warmth, even although the air between your hand and the flame may be quite cold. When heat is in this way conveyed from a source of heat to a body without heating the intermediate substance, it is said to be conveyed by **radiation.**

If you put up an umbrella at midday you find considerable protection from the heat of the sun. If the heat of the sun were conveyed to you by conduction or convection through the air, the putting up of the umbrella would make little difference. The heat of the sun reaches the earth by the process of radiation, and this *radiant heat* is stopped by the umbrella.

We may sum up what has been learnt about the conveyance of heat. There are three different ways in which heat may pass, by *conduction*, *convection*, or *radiation*.

Conduction of heat is the passing of heat from particle to particle of a substance; the particles themselves do not travel. Solids are heated by conduction.

In convection the heated particles of the substance move about carrying the heat with them; convection takes place in liquids and gases, but not in solids.

In the process of radiation heat passes directly from one body to another, without heating the intermediate substance. Radiation can take place across empty space, such as there is between our atmosphere and the sun.

ADDITIONAL EXPERIMENTS.

EXPERIMENT 20.*—To show some of the effects of the conduction of heat by wire gauze.

Lower a piece of fine gauze over the flame of the gas or spirit lamp. The gauze conducts heat so quickly that

the gas or vapour above the gauze does not get hot enough to ignite. Put out the flame. Light the gas above the gauze. (If you are using a spirit lamp, light the lamp and hold the gauze over the wick ; blow out the flame and rapidly re-light it above the gauze.) The gauze conducts the heat so quickly that the gas underneath the gauze does not get hot enough to ignite.

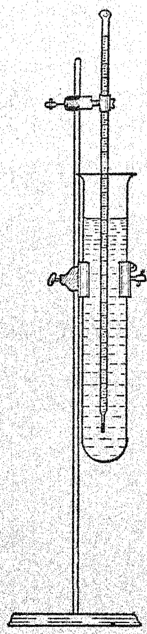


FIG. 10.

EXPERIMENT 21.*—To show that water is a poor conductor of heat.

Half fill the given test-tube with cold water, and support it as shown in Fig. 10.

Clamp a thermometer with the bulb almost touching the bottom of the test-tube.

Heat some oil in an evaporating dish to about 100° C. Pour the oil gently down the stem of the thermometer, so that it floats on the water. Note carefully the rise in temperature of the water. You will find that the temperature rises very slowly, thus proving that the water has conducted heat very slowly from the oil to the bulb of the thermometer.

EXPERIMENT 22.*—To show the principle on which rooms should be ventilated by convection currents.

Fix a candle in a shallow vessel (*e.g.* the cover of a tin), containing a little water. Light the candle and place a lamp chimney over it. You will notice that after a short

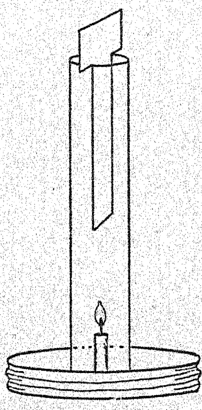


FIG. 11.

time the flame of the candle gets very low, and perhaps goes out. The reason is that the gases formed by the burning candle prevent fresh air from reaching it, and so it cannot burn. Place a cardboard partition in the chimney, light the candle, and again place the chimney over the candle

(Fig. 11). You will see that the candle will now burn more brightly. The reason is that the gases pass up one passage and fresh air passes down the other passage to take their place. If you place a smoking match first at one side of the partition and then at the other, you will be able to notice the effects of these *convection currents* ; on the side on which the fresh air is passing into the chimney, smoke from the match is carried down the tube, but on the other side the gases from the candle, passing out of the chimney, blow the smoke of the match away from the passage.

From this experiment we learn that in every room there should be two openings,—one for fresh air to pass in, and one for heated and impure air to pass out.

CHAPTER V.

(NOTE.—*This chapter may be postponed until after Chapter VI. has been done.*)

HYDROSTATICS.

RELATIVE DENSITY (SPECIFIC GRAVITY).

YOU have found out by experiment that all substances have not the same density. It is useful to find out how these densities compare with one another. This may be done by selecting one substance as the standard, and seeing how many times the density of this standard is contained in the density of the given substance.

Water is selected for this comparison. The density of a substance compared with the density of water is called its relative density. For instance, the density of iron is 7·2 gm. per c.c., and the density of water may be taken for all practical purposes to be 1 gm. per c.c.

Hence the *relative density* of iron is

$$\frac{\text{Density of iron}}{\text{Density of water}}, \text{ or } \frac{7{\cdot}2 \text{ gm. per c.c.}}{1 \text{ gm. per c.c.}}, \text{ or } 7{\cdot}2.$$

Notice that the Relative Density of a substance is simply a number; there are no units.

You see also from the example that because the density of water is 1 gm. per c.c., the Relative Density of a substance in Metric units has the same *numerical* value as its density.

Sometimes the term **Specific Gravity** is used instead of the term Relative Density.

Definition. The Relative Density (Specific Gravity) of a substance is the ratio between its density and the density of water. We may write this definition thus:

Relative Density (R.D.) of a substance

$$= \frac{\text{Density of substance}}{\text{Density of water}}, \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

or R.D. of substance

$$= \frac{\text{Mass of substance} \div \text{volume of substance}}{\text{Mass of water} \div \text{volume of water}},$$

or, taking *equal volumes* of the substance and water, we may say:

R.D. of substance

$$= \frac{\text{Mass of any body made of the substance}}{\text{Mass of an equal volume of water}}. \quad \ldots.(2)$$

TO CALCULATE THE RELATIVE DENSITY OF A SUBSTANCE.

(1) *In the case of substances whose densities are known*, use the formula (1):

$$\text{R.D.} = \frac{\text{Density of substance}}{\text{Density of water}};$$

e.g. find the Relative Density of linseed oil, whose density is 0·94 gm. per c.c.

$$\text{R.D. of linseed oil} = \frac{0{\cdot}94 \text{ gm. per c.c.}}{1 \text{ gm. per c.c.}} = 0{\cdot}94.$$

(2) *In the case of substances whose densities are not known*, it is better to work from formula (2):

$$\text{R.D.} = \frac{\text{Mass of any body made of the substance}}{\text{Mass of an equal volume of water.}};$$

e.g. a bottle weighs 40 g.m. When full of water it weighs 72 gm., and when full of turpentine 62·8 gm. Find the relative density of turpentine.

Mass of water filling the bottle = (72 − 40) gm. = 32 gm.
,, turpentine ,, ,, = (62·8 − 40) gm. = 22·8 gm.

Hence R.D. of turpentine $= \frac{22\cdot8 \text{ gm.}}{32 \text{ gm.}} = 0\cdot71$.

EXERCISE 5.

1. Find the relative density of the following substances, whose densities are given :

Sea water (density = 1·02 gm. per c.c.).
Lead (density = 11·4 ,,).
Copper (density = 550 lb. per cu. ft.; density of water in British units = 62·5 lb. per cu. ft.).
Iron (density = 451 lb. per cu. ft.).

2. A bottle weighs 42 gm. Filled with water it weighs 77 gm.; filled with oil it weighs 62 gm. Find the relative density of the oil.

3. A bottle full of water weighs 54·6 gm. When 51·3 gm. of lead are introduced, displacing some of the water, it weighs 101·4 gm. Find the relative density of the lead.

4. A bottle weighs 87 gm. when full of water. When 38·5 gm. of sand are put in, displacing some of the water, it weighs 110·1 gm. Find the relative density of the sand.

5. If the weight of an iron cylinder is 55·6 gm., and the relative density of iron is 7·8, what is the volume of the cylinder?

6. The diameter of a copper sphere is 4·2 cm. Find its weight. Relative density of copper = 8·8.

7. How many lead shot, each 0·3 cm. in diameter, can be made from 80 gm. of lead? Relative density of lead = 11·4.

The Relative Density Bottle.—This is used for finding the relative density of liquids, or of solids which are in very small pieces, such as sand or lead shot. The best form of relative density bottle (Fig. 12) has a hole through the

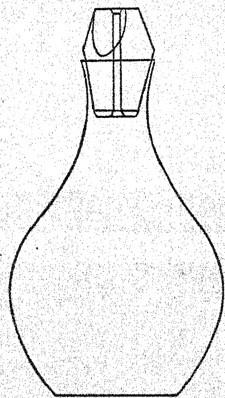


FIG. 12.

stopper, or a groove along the side of the stopper. When the bottle is filled with a liquid, and the stopper inserted, the excess liquid will pass out through the hole or groove. You must be careful that there are *no air bubbles* left inside the bottle.

EXPERIMENT 23.—To find the relative density of salt solution.

You are given a relative density bottle. See that it is dry inside as well as outside; if it is not dry inside you should dry it by means of a current of hot air, which you may obtain by driving air from the blow-pipe bellows through a piece of tubing (hard glass or copper) heated in a flame.

Weigh the bottle.

Fill the bottle with water, replace the stopper, and, after seeing that there are *no air bubbles*, carefully dry the outside.

Weigh the bottle and water.

Pour out the water and rinse the bottle with a little salt solution. Pour this solution away. Now fill the bottle with fresh salt solution, replace the stopper, dry the outside, and weigh.

The difference between the first and second weighings will give you the mass of water required to fill the bottle, whilst the difference between the first and third weighings will give you the mass of salt solution required to fill the bottle. From these results you obtain the relative density of salt solution.

Enter your results thus :

Mass of bottle empty - -	=	gm.
Mass of bottle and water . -	=	gm.
Mass of bottle and salt solution	=	gm.
Mass of water - - -	=	gm.
Mass of salt solution - -	=	gm.

$$\text{Relative density of salt solution} = \frac{\text{mass of salt solution}}{\text{mass of equal volume of water}}$$

$$= \frac{\text{gm.}}{\text{gm.}}$$

$$=$$

Repeat the experiment again, and find the average of the two results.

EXPERIMENT 24.*—To find the relative density of lead shot, using a relative density bottle.

You are given a relative density bottle and some lead shot. Take about 50 gm. of the lead shot, and weigh it. In order to prevent the shot scratching the balance pan, first place sheets of paper, one on each pan, and adjust their weights by tearing off small pieces, so that they will exactly balance one another. Place the shot on one sheet of paper and the weights on the other.

Fill the bottle with water, replace the stopper, and dry the outside. Place the bottle full of water on the same pan as the shot and weigh. Now place the shot inside the bottle; see that the bottle is full of water; replace the stopper; dry the outside of the bottle, and weigh the bottle containing shot and water. The difference between this weighing and the previous one gives you the mass of the water displaced by the shot—that is the mass of water having the same volume as the shot. Divide the mass of the shot by the mass of the water, and so obtain the relative density of the lead shot.

Enter your results thus:

Mass of lead shot - - - - - -	=	gm.
Mass of bottle of water and shot on pan	=	gm.
Mass of bottle containing water and shot	=	gm.
Mass of water displaced by the shot -	=	gm.

$$\text{Relative density of lead shot} = \frac{\text{mass of lead shot}}{\text{mass of equal volume of water}}$$

$$= \frac{\text{gm.}}{\text{gm.}}$$

$$=$$

Repeat the experiment again, and find the average of the two results.

THE PRINCIPLE OF ARCHIMEDES.

You know from experience that when you immerse your hand in water a backward push is felt. This upward push is called an *upthrust*. Hold a piece of brick under water; the brick does not seem to be as heavy as in air, because there is an upthrust from the water acting against its weight. Such an upthrust is exerted by all liquids on bodies immersed.

There is an important connection between the upthrust on a body and the weight of liquid displaced.

EXPERIMENT 25.—To find the relationship between the upthrust on a body immersed in water and the weight of the water displaced.

You are given a heavy solid of regular form. Suspend the solid from the hook of the balance, by a light cotton

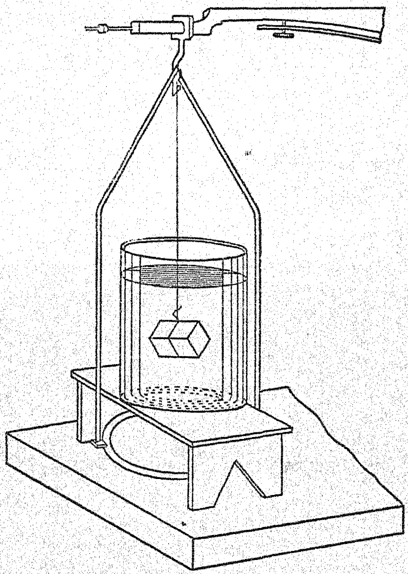


FIG. 13.

thread; it should be suspended at such a height that it may afterwards hang freely in a beaker of water arranged as in Fig. 13. Weigh the suspended solid. Place a stool over the balance pan (Fig. 13), put a beaker of water on the stool and weigh the solid in water. In doing this be careful that the solid does not touch the sides of the beaker, or the surface of the water when the beam is raised.

The solid weighs less in water than in air, because the upthrust from the water is acting against the weight of the

solid; *the amount of the upthrust is found by subtracting the weight of the body in water from its weight in air.*

To find the weight of water displaced by the body, proceed thus:

Suppose the volume of the body is 8 c.c., then the volume of water displaced by it is 8 c.c.; but 1 c.c. of water weighs 1 gm. Hence the weight of water displaced by the body is 8 gm.

Enter your results thus:

Volume of Solid.	**Weight of water displaced by Solid.**	Weight of Solid in air $= W_1$.	Weight of Solid in water $= W_2$.	**Upthrust on Solid** $= W_1 - W_2$.
c.c	gm.	gm.	gm	gm

NOTE.—Experiment 25 may be performed at the lecture table by the teacher, assisted by the pupils.

Compare the results in the second and fifth columns of the above table. The conclusion to which this experiment leads is known as the **Principle of Archimedes,** and may be stated as follows:

When a body is immersed in water the body is pressed vertically upwards with a force equal to the weight of the water displaced by the body.

This principle is true for floating bodies, and is true also for *any* liquid. We may state it in a more general form as follows:

When a body is immersed, either wholly or partially, in a liquid it is pressed vertically upwards with a force equal to the weight of liquid displaced.

EXAMPLE 1.—*What volume of water will* 500 *c.c. of wood of density* 0·82 *gm. per c.c. displace?*

Since the wood floats in water the upthrust from the water must be equal to the weight of the wood.

Hence upthrust $= 0{\cdot}82 \times 500$ gm.

$= 410$ gm.

But, as we have seen above, the upthrust is equal to the weight of water displaced.

Hence the weight of water displaced by the wood is 410 gm.

Hence the *volume* of water displaced by the wood is 410 c.c. (because 1 c.c. of water weighs 1 gm.).

EXAMPLE 2.—*A tin can of weight* 5·1 *gm. and volume* 46·7 *c.c. floats in water. What weight of shot must be placed in it so that it will just float?*

Let W gm. be the weight of shot required to make the rim of the can sink to the level of the surface of the water.

The total weight causing the can to sink will be $(W + 5{\cdot}1)$ gm. This will be balanced by the upthrust from the water; this upthrust is (Archimedes' Principle) equal to the weight of the water displaced. The volume of the can is 46·7 c.c. Hence the weight of water displaced by it is 46·7 gm.

Hence $W + 5{\cdot}1 = 46{\cdot}7$,

or $W = 46{\cdot}7 - 5{\cdot}1$

$= 41{\cdot}6$

Hence the weight of shot required is 41·6 gm.

EXERCISE 6.

1. The volume of a piece of wood is 732 c.c., and its density is 0·52 gm. per c.c. What weight of water will it displace?

2. A raft of dimensions 3 ft. by 15 ft. by 10 ft. weighs 4 tons. Find the greatest load it will carry; 1 cu. ft. of water weighs 62·5 lbs.

3. A piece of wood 6 cm. by 3 cm. by 4 cm. weighs 44 gm. What volume is above water when it floats?

4. A circular sheet of ice 20 yd. in diameter and 6 in. thick floats in fresh water. What weight in tons can it support? (1 cu. ft. of ice weighs 57·4 lb.)

5. A cylinder of wood (relative density = 0·52) floats in water. What weight must be added so that it will just sink, if the cylinder is 18 cm. high and 6 cm. in diameter?

6. A piece of wax has a volume of 80 c.c. Its relative density is 0·88. Calculate its weight, and also the volume of it beneath the surface when it floats in water.

7. Find the upthrust due to the liquid on 95 c.c. of iron:

(*a*) When totally immersed in pure water.

(*b*) When half immersed in oil (relative density = 0·52).

8. 18 c.c. of copper (relative density = 8·8) float in mercury (relative density = 13 6). Find the volume of mercury displaced.

9. 1 cu. ft. of water weighs 62·5 lb. What volume of a vessel goes under water when 400 tons of coal are taken on board?

10. A rectangular block of wood of relative density 0·48 and 18 inches high floats in water with its axis vertical. To what depth will it be immersed?

11. A cylinder of wood floats in water with its axis vertical. If one-quarter of it be above the surface, what is the relative density of the wood?

12. A prism 2 cm. by 3 cm. by 10 cm. floats with 55 c.c. immersed in water. What is the relative density of the material?

TO CALCULATE RELATIVE DENSITY BY ARCHIMEDES' PRINCIPLE.

Upthrust on a body immersed = weight of water displaced by the body.

But Relative Density of a body

$$= \frac{\text{mass of body}}{\text{mass of an equal volume of water}}$$

$$= \frac{\text{weight of body}}{\text{weight of an equal volume of water}}$$

$$= \frac{\text{weight of body}}{\text{weight of water displaced by body}}$$

$$= \frac{\text{weight of body}}{\text{upthrust on body when immersed}}.$$

EXAMPLE.

A solid weighs 130 *gm. in air and* 94 *gm. in water, what is the relative density of the solid?*

$$\text{R.D.} = \frac{\text{weight of body}}{\text{upthrust on body}}$$

$$= \frac{\text{weight of body}}{\text{weight of body in air} - \text{weight of body in water}}$$

$$= \frac{130 \text{ gm.}}{130 \text{ gm.} - 94 \text{ gm.}}$$

$$= \frac{130 \text{ gm.}}{36 \text{ gm.}}$$

$$= 3{\cdot}61.$$

EXERCISE 7.

1. A solid weighs 48 gm. in air and 40 gm. in water. What is its relative density?

2. A piece of copper wire weighs 88 gm. in air and 78 gm. in water. What is the relative density of copper?

3. The relative density of zinc is 6·9. A piece of it weighs 58 gm. What will it weigh in water?

4. A piece of iron wire weighs 12 gm. in air and 10·4 gm. in water. What is its volume?

5. A stone weighs 25·25 gm. in air, 16·50 gm. in water, and 14·39 gm. in oil. Find (1) the volume of the stone, (2) the relative density of the stone, and (3) the relative density of the oil.

EXPERIMENT 26.—To find the relative density of a substance which sinks in water.

You are given a small piece of metal. Weigh it. Find also its weight in water, suspended as the solid was suspended in Experiment 25 (Fig. 13). If there are any air bubbles on the metal when it is immersed, unhook the thread and jerk the metal up and down in the water to get rid of the bubbles.

Enter results thus:

Weight of metal in air -	= gm.	...................(1)
Weight of metal in water -	= gm.	...................(2)
Upthrust on metal = (1) − (2)	= gm.	

$$\text{R.D. of metal} = \frac{\text{weight of metal in air}}{\text{upthrust on metal immersed}} = \frac{\text{gm.}}{\text{gm.}} =$$

Repeat this experiment again, and find the average of the results.

If the substance whose relative density you want to find floats in water, you cannot use the method of the last experiment directly; but you may get over the difficulty by attaching the light solid to a sinker, as in the following experiment.

EXPERIMENT 27.—To find the relative density of a substance which floats in water.

Weigh the given body (a piece of wax). Weigh the given sinker (a piece of lead with a pin soldered into it). Fix the wax on the pin of the sinker, and find the weight of the wax and sinker together in water.

The difference between the weight of the wax and sinker in air and the weight of the wax and sinker in water will give the upthrust on the wax and sinker.

Then weigh the sinker in water, and by subtracting this result from the weight of the sinker in air obtain the upthrust on the sinker.

To get the upthrust on the wax subtract the upthrust on the sinker from the upthrust on the wax and sinker.

Enter results thus :

Weight of wax in air - - - -	=	gm. .....(1)
Weight of sinker in air - - - -	=	gm. .....(2)
Weight of wax and sinker in air = (1) + (2)	=	gm. .....(3)
Weight of wax and sinker in water -	=	gm. .....(4)
Upthrust on wax and sinker = (3) − (4) -	=	gm. .....(5)
Weight of sinker in water - - -	=	gm. .....(6)
Upthrust on sinker = (2) − (6) - -	=	gm. .....(7)
Upthrust on wax = (5) − (7) - - -	=	gm.

$$\text{R.D. of wax} = \frac{\text{weight of wax}}{\text{upthrust on wax immersed}}$$

$$= \frac{\text{gm.}}{\text{gm.}}$$

$$=$$

Repeat the experiment, and find the average of the results.

ADDITIONAL EXPERIMENTS.

EXPERIMENT 28.*—To find the relative density of sand.

Weigh out 30 gm. of sand. Find the weight of a relative density bottle full of water together with the sand in the

same balance pan, as in Experiment 24. Empty the water from the bottle. Carefully pour the sand into the empty bottle, using a paper funnel. Fill up with water, replace the stopper, and shake well to remove air bubbles from the sand. When all the air bubbles have been removed fill up with water and proceed as in Experiment 24.

EXPERIMENT 29.*—To find the relative density of a liquid by the Principle of Archimedes.

You are given some salt solution whose relative density you have to find, and a solid (a glass stopper is suitable) which sinks in the liquid. Weigh the solid first in air, and then completely immerse in water, and find the upthrust as in Experiment 26.

Dry the solid and weigh it completely immersed in the liquid. The difference between this weighing and the first (*i.e.* in air) will give you the upthrust due to the liquid, that is, the weight of a volume of the liquid equal to that of the solid. Also the upthrust due to the water gave you the weight of a volume of water equal to that of the solid.

You have now the weights of equal volumes of water and liquid, from which you can find the relative density of the liquid.

Enter your results thus:

Weight of solid in air - - - =	gm.	........(1)
Weight of solid in water - - - =	gm.	........(2)
Upthrust on solid in water = (1) – (2) =	gm.	
Weight of solid in liquid - - =	gm.	........(3)
Upthrust on solid in liquid = (1) – (3) =	gm.	

$$\text{R.D. of liquid} = \frac{\text{upthrust on solid in liquid}}{\text{upthrust on solid in water}}$$

$$= \frac{\text{gm.}}{\text{gm.}}$$

$$=$$

EXPERIMENT 30.*—To find the volume of an irregular solid by Archimedes' Principle.

Find the upthrust on the solid by Archimedes' Principle, employing the method of Experiment 26 for a solid which sinks in water, and that of Experiment 27 for a solid which floats in water. The upthrust gives the weight of water displaced by the solid; knowing that 1 c.c. of water weighs 1 gm., you thus find the volume of water displaced, *i.e.* the volume of the body.

EXPERIMENT 31.*—To find the diameter of a wire by Archimedes' Principle.

Find the volume of the wire by the method adopted in Experiment 30.

Knowing the volume and length of the wire, calculate its diameter, taking the wire to be a cylinder.

CHAPTER VI.

CHEMISTRY.

COMMON PROPERTIES OF SUBSTANCES.

WHEN you try to describe anything you do so by giving an account of its properties. The properties of a thing are what it appears to be like, and the way in which it behaves. Take sugar as an example. Sugar is a solid, is sweet to taste, dissolves in water, is white in colour, and will burn with a pungent smell. When you have said this you have given an account of some of the properties of sugar.

A substance is always recognised by its properties. If you were asked what the substance is which shines like silver, but is a liquid much heavier than water, and although it is a liquid does not wet either glass or your hand when you touch it, which has no smell and which is so dense that stones will float upon it, you know at once that the substance is mercury.

It is very important, therefore, to describe the properties of substances very *fully* and very *accurately*.

The most easily discovered of the common properties by which we describe and recognise things are:

State, colour, taste, smell, feel, effect of heat, malleability, and density.

By **state** is meant whether a substance is a solid, a liquid, or a gas.

When you examine a substance which is a solid you must place a little in a crucible or test-tube and warm it in the flame of your burner to see whether it melts readily or not.

In describing **colour** you should at the same time note whether a substance is *transparent*, which means that you can see through it; *translucent*, which means that the substance will let light pass through it, but that it is not transparent; or *opaque*, which means that no light can pass through it at all.

Thus window glass is transparent, paraffin wax is translucent, and charcoal is opaque.

Taste.—Never taste anything in the laboratory unless you are told to do so by your teacher, because many chemicals are very poisonous When the teacher tells you to taste anything, the best way is to take a little on the tip of your finger and then put it on your tongue. Notice whether the taste is sharp and sour; if so, it is called *acid*. Whether it is saltish; if so, it is called *saline*. Whether it is *sweet*, or *burning*, or *cooling*.

Smell.—To smell things is not so dangerous as to taste them, but do so carefully, as many chemicals have a very powerful and choking odour.

Notice whether the smell is pleasant, or sharp and *pungent*, making you inclined to sneeze; or *choking*, making you inclined to cough and choke.

Feel.—Rub the substance between your fingers and notice whether it is *gritty* like sand, or *smooth* like French chalk, or *soapy*, or *waxy*, or *oily*, and so on.

Effect of Heat.—If the substance is solid, see whether it will burn. To find this out place some of it on a knife blade or on a piece of a clock spring and heat it in the flame of your gas burner or spirit lamp. Note whether the flame is smoky. Notice also whether the substance melts

easily, changes colour, or in any other way, or whether it breaks up into smaller pieces when it is heated.

Malleability.—If a solid can be beaten out into thin sheets like lead and gold, it is said to be very *malleable*. If it breaks up into pieces when it is hammered or beaten, it is said to be *brittle*. To test whether a substance is malleable or brittle put it on an iron block and hit it hard with a hammer. If it breaks put it into a mortar, and rub it with the pestle and see whether it is easily powdered.

Density really means the mass of unit volume of a substance; but in describing the common properties of a substance, it is sufficient to note whether the substance is very light or very heavy; whether, for instance, it will float or sink in water, and so on.

EXPERIMENT 32.—To find out some of the common properties of paraffin wax, salt, lead, magnesium, sulphur.

Examine paraffin wax and verify the following results:

Substance, - - -	Paraffin wax.
State, - - - -	Solid.
Colour and form, - -	White, translucent.
Taste, - - - -	None.
Smell, - - - -	None.
Feel, - - - -	Waxy and soft.
Effect of heat, - - -	Melts and then burns with a smoky flame.
Malleability, - - -	If warm it is malleable, but if very cold it is brittle.
Density, - - - -	Lighter than water.

Examine salt, lead, magnesium, sulphur, and blue vitriol in a similar manner, and write your results in the manner shown above for paraffin wax.

There are other important properties which cannot be determined by observation only. For these certain experiments must be performed. Such properties are hardness, solubility, crystalline or non-crystalline form.

EXPERIMENT 33.—To compare the relative hardness of some common things.

(i) Place before you on the table a steel knife, a piece of glass, some wax, some roll sulphur, some zinc, some lead, a piece of copper, a piece of wood, some magnesium ribbon or wire. These are all solids, and you would say they are all more or less *hard*.

Take the copper and see whether you can scratch or cut all the other substances with it, or not. You will find some can be scratched and some cannot. Write down the result as follows:

Copper will scratch:

(1) Wax,
(2)
(3) etc.

Copper will not scratch:

(1) Iron,
(2)
(3) etc.

All the substances which copper will not scratch are harder than copper, and copper is harder than the substances which it can scratch.

(ii) Now arrange all the substances on the table in a line, so that the substances are in such order that the one on the right will scratch the one next to it on the left.

(iii) Then make a list with the hardest substance coming first and the softest coming last.

EVAPORATION AND SOLUBILITY.

When a wet cloth is hung out in the air or in the sun it soon becomes dry. The water in the cloth has disappeared. If the air is cold and damp the cloth will dry slowly, but if the air is warm and dry, the cloth will dry very quickly.

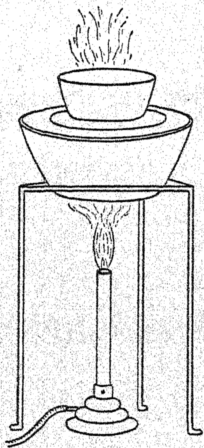


FIG. 14.

Just in the same way, if you take some water in a dish and leave it, in a day or two the water will dry up and disappear. If you heat the dish the water will disappear more quickly.

This process of drying up is called "*evaporation*." In chemistry, when we wish to evaporate a liquid quickly, we place the liquid in a porcelain dish and heat the dish. If it is necessary to be very careful, so as to avoid the liquid spurting, the dish is placed on a copper vessel called a water-bath, and the water-bath is heated.

EXPERIMENT 34.—To find whether anything is left behind when water evaporates.

Clean and weigh a small porcelain dish.

Pour into it 10 c.c. of tap or well water.

Place the dish on a water-bath and heat the latter till all the water in the dish has evaporated. Wipe the *bottom* of the dish with a clean cloth till it is quite dry. Allow the dish to cool and again weigh.

Record your result thus:

Weight of dish - - - -	=
Weight of dish after adding water and evaporating - - - - -	=
Gain or loss in weight - - -	=

Describe the appearance of what is left in the dish.

Repeat the experiment, using distilled water.

SOLUBILITY.

What happens when a lump of sugar is placed in warm water? The sugar crumbles up and disappears, and the water tastes sweet. The sugar is said to have *dissolved* in water, or to be *soluble* in water. After the sugar has dissolved, the liquid is said to be a *solution* of sugar in water.

Sometimes it is very easy to see whether a substance dissolves or not. Thus it is clear that sugar dissolves, because it makes the water taste sweet, or that copper sulphate dissolves because it makes the water blue in colour.

Sometimes it is not very easy, and it is only possible to find out after *filtering* the liquid and *evaporating*, after it has been well shaken or stirred up with the solid substance.

EXPERIMENT 35.—To fold and use a filter paper.

Fold the paper across the middle; it will have the appearance of (1). Then fold it again as in (2). It will now

make hollow cone, or little cap. Place this in a funnel, carefully fitting it so that it touches the funnel all round. Moisten it with water, and again gently press it against the side of the funnel.

Now place the funnel and filter in a stand.

NOTE.—*The filter when folded must never reach above the top rim of the funnel.*

Place a beaker under the funnel and pour some clear water into the filter, so that the filter is a little more than

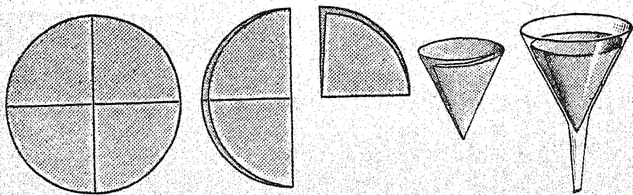


FIG. 15.

half full. Note that the water quickly passes through the filter.

Now take a little chalk and finely powder it in a mortar, mix it with some water, so that you have a milky-looking liquid. Pour some of this on to the filter. Note that the water still passes through quite clear.

The liquid which passes through a filter is called the *filtrate*.

Filter paper is really only a kind of blotting-paper. Blotting-paper easily soaks up ink. This is because it is full of small pores or holes into which the ink can run. It is called *porous*. These pores are very small, so small that the powdered chalk cannot pass through although the water can.

When you filter, the chalk is left behind on the filter and the water passes through.

NOTE.—*In filtering, the liquid must never reach to the top of the filter paper, because it could then creep down between the paper and the funnel.*

EXPERIMENT 36.—To determine whether a substance will dissolve in water.

Measure out 50 c.c. of distilled water into a clean beaker. Finely powder 20 grams of the substance, and put this into the water. Stir well for 5 minutes with a glass rod. Filter the mixture and collect the filtrate in a clean evaporating basin. Place this in a *water-bath* and evaporate the solution until the dish is quite dry. If you find a *residue* in the dish, it shows that the substance dissolves in water.

Perform this experiment with water and lime, water and salt, water and marble.

OTHER SOLVENTS BESIDES WATER.

When any substance dissolves in water, water is called the *solvent*. A solvent is the liquid in which a substance dissolves. There are many substances which will not dissolve in water, but which will dissolve in other solvents; for instance, alcohol will dissolve many fats and waxes, and ether and petrol will do the same.

EXPERIMENT 37.—To determine in which solvent substances will dissolve.

Take alcohol, petrol, and water as the solvents, and determine in which of these

(1) Paraffin wax, (2) Sugar,
(3) Salt,

will dissolve. Take care that in evaporating alcohol and petrol the flame of the lamp does not get near the evaporating dish, or they will catch fire and burn.

SOLUBILITY OF LIQUIDS AND GASES.

Solids are not the only substances which can dissolve in liquids. For instance, if you pour one or two cubic centimetres of alcohol into an equal amount of water, the two substances will mix together, and you may say that the alcohol has dissolved the water or that the water has dissolved the alcohol. In the case of two liquids, however, we usually say that they "mix."

Gases will also dissolve. When a bottle of soda water is opened a great deal of gas comes out, which was dissolved in the water. Even ordinary tap water contains air dissolved in it. If a beaker of tap water is gently heated, bubbles of gas begin to form on the sides of the beaker long before the water boils. These are bubbles of dissolved air. The air was probably dissolved when the water fell as rain. Unlike most solids, gases are *less* soluble in hot water than they are in cold.

EXPERIMENT 38.—To determine the temperature at which air is given up by the school supply of water.

Half fill a beaker with water and heat it on a tripod stand over the flame. Notice when bubbles form on the sides of the beaker, and take this temperature (1). Stir gently with the thermometer and note the temperature when bubbles begin to rise briskly through the water (2). Finally note the temperature when real boiling takes place (3).

CRYSTALS.

When a substance is dissolved in a solvent, and the solvent is allowed to evaporate slowly, very often the substance will separate in regular shapes, which are called crystals.

Crystals may be of many different shapes and sizes and colours, but they resemble one another in having smooth sides and in having angles between the sides. There is no such thing as a crystal in the shape of a sphere.

EXPERIMENT 39.—To form crystals from salt.

Take some finely powdered salt and make a saturated solution. Place this on one side in an open dish for two days, and then examine the residue. You will find small crystals in the shape of cubes. Use a lens if necessary.

EXPERIMENT 40.—To form large crystals of alum.

Make a saturated solution of alum and place on one side till crystals begin to form. Turn the crystals over daily in the solution till you get some about the size of

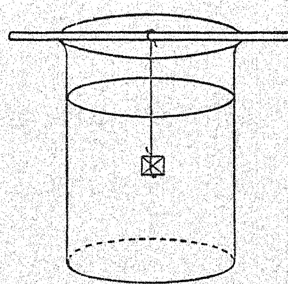


FIG 16.

a pea. Select the most regular of these and tie it on to a long horse hair.

Place some saturated solution in a beaker and suspend the crystal so that it hangs in the solution. This is done by tying the horse hair round a glass rod and placing this across the top of the beaker (Fig. 16).

Allow this to stand, and examine it day by day. The crystal will "grow," and in a few days a large regular crystal of alum will be formed.

EXPERIMENT 41.—To show that the size of crystals formed from a solution depends on the rate at which they form.

Make a hot saturated solution of potassium nitrate in a test-tube, and cool the tube in cold water. A white powder settles down at once at the bottom of the tube. Look at this through a lens. Is it crystalline? Again, make a hot saturated solution, but this time allow the tube to cool slowly. Note that crystals are formed which are much larger and finer than when the solution was rapidly cooled.

THE FORMATION OF CRYSTALS FROM SOLUTIONS.

When a cold, saturated solution is allowed to evaporate slowly crystals are formed, and when a hot saturated solution is allowed to cool crystals are formed. In the first case water is evaporated, so the solution contains more dissolved substance than it can hold and has to give it up. In the second case, as the hot liquid cools it cannot hold so much dissolved substance in solution and so it too has to give up some solid.

Experiments with crystals should be performed in warm, dry weather, because water will then evaporate more quickly than in damp, cold weather. If evaporation takes place *very* quickly small crystals are formed. The same takes place when a *hot* saturated solution is allowed to cool. As the solution cools it can no longer keep the substance dissolved, and so the dissolved substance separates out quickly, and the crystals formed are small.

There are thus two methods of forming crystals from solutions. The first is to allow a saturated solution to evaporate, and the second is to allow a *hot* saturated solution to cool.

The slower the evaporation, and the slower the cooling, the larger the crystals will be.

WATER OF CRYSTALLIZATION.

It is a strange fact that many solid crystals contain water. The water is not in the liquid form, but is actually part of the solid crystal.

EXPERIMENT 42.—To show that alum crystals contain water of crystallization.

Take some crystals of alum, dry them with blotting-paper, and then powder them. Place the powder in a test-tube and carefully heat the tube. Notice that water is formed on the sides of the tube. This is the "water of crystallization."

Repeat with salt, copper, sulphate, nitre, crystals of sodium carbonate (washing soda), and record which have water of crystallization and which have none.

Note also any other changes which occur when these substances are heated.

MORE ABOUT CRYSTALS.

Crystals may be formed without the substance being dissolved. For example, many minerals which will not dissolve in water are found in beautiful crystalline shapes, such as the diamond. These have been formed by the substances slowly cooling from the melted state. The interior of this earth is extremely hot; so hot that the minerals have melted, and on cooling the crystals are formed.

EXPERIMENT 43.*—To form crystals of sulphur.

Take some pieces of sulphur in an earthen crucible and heat gently till all is melted. Allow to cool till the top *just* begins to become solid. Then quickly prick two or three holes in the top and pour out the liquid sulphur. If the sulphur catches fire, while you are heating it, remove the flame and extinguish the burning sulphur by covering

the crucible with a piece of metal. There is no danger, so do not be nervous or hurry unduly. To pour out the sulphur you may hold the crucible in a pair of tongs or in a duster. Cut out the top crust of sulphur and examine the crystals in the crucible.

MECHANICAL MIXTURES.

EXPERIMENT 44.—To separate a mixture of salt and sand.

Finely powder about 5 grams of salt and thoroughly mix it with an equal quantity of powdered sand.

Examine the mixture through a lens.

Place the mixture in a flask and shake it for several minutes with enough water to dissolve all the salt, about 25 c.c. Then filter the solution. Rinse out the flask with one or two cubic centimetres of water, and wash the residue on the filter paper first with this water from the flask, and then with a little pure water from the wash bottle.

Leave the filter to dry; what does it contain?

Evaporate the filtrate to dryness; what is it?

The sand and salt have been separated by *mechanical means*.

EXPERIMENT 45.—To separate a mixture of iron filings and sulphur.

Mix about 5 grams of each of these two substances. Neither will dissolve in water, so they cannot be separated in the same manner as salt and sand. Spread the mixture out on a sheet of paper and run a magnet along the powder. What happens?

EXPERIMENT 46.—To separate a mixture of powdered charcoal and sand.

Sand and charcoal have very different densities; sand is denser than water, but charcoal is less dense.

Put the mixture in a beaker and pour water on to it. Then stir it well. The sand will sink to the bottom of the beaker, but the charcoal will float on the surface of the water. When the sand has settled, carefully pour off the water through a filter paper and pour some more water on the sand; stir again and again allow it to settle, again pouring the water through the filter. The filter will now contain the charcoal, and the sand will remain in the beaker.

EXERCISE 8.

How would you attempt to separate a mixture of powdered charcoal and nitre, or a mixture of iron filings and salt?

CHEMICAL COMPOUNDS.

You have seen that when two substances are mixed together they can often be separated again by mechanical means. We call such mixtures *mechanical mixtures*. Sometimes, however, a little thing will set up an action between the substances, and make it impossible to separate them again.

EXPERIMENT 47.—To heat a mixture of iron and sulphur.

Mix 1 gram of iron filings and 4 grams of powdered sulphur and heat the mixture in a test-tube. Note down carefully all that you see happening in the tube. When the "action" is over, allow the tube to cool and break it open. Powder what is left in the tube. Attempt to separate the iron and sulphur by means of a magnet.

EXPERIMENT 48.—To heat a mixture of copper and sulphur.

Repeat the last experiment, using copper filings in place of iron filings.

CHEMICAL COMBINATION.

In both these experiments something takes place which is quite different from merely mixing. The action of heat causes the iron and sulphur to form a *new substance* different from either iron or sulphur, which is called sulphide of iron. It is different in colour, it is no longer attracted by a magnet; in fact, it is different in every way from either iron or sulphur. The iron and sulphur have joined together and formed a new compound. Such an action is called *chemical combination*, and the new substance is called a *chemical compound*.

In the case of copper and sulphur the new compound is called sulphide of copper.

Chemical compounds cannot be separated into their parts by mechanical means.

CHEMICAL AND PHYSICAL CHANGE.

When you take a lump of sulphur and break it up it is still sulphur. If you heat it till it melts, the hot liquid is still sulphur.

In the same way water when frozen is still water, and when boiled, the steam is still water vapour. Both ice and steam can be easily converted into ordinary water again. These changes are *physical changes*. The *state* of the substance is changed.

Chemical change is the name given to the change which takes place when the substance itself is changed. For instance, when sulphur and iron are heated chemical change takes place. But there are many other examples.

EXPERIMENT 49.—To heat a mixture of charcoal and nitre.

Take a gram of nitre and powder it, and then mix it with an equal quantity of powdered charcoal. Place half the

mixture on an iron plate, and heat it over the bunsen burner. Take great care to hold your head *away* from the plate while you are heating it.

Is the change a physical or chemical one?

EXPERIMENT 50.—To show that chemical change takes place when iron is placed in copper sulphate solution.

Take a strong solution of copper sulphate, and in it place a piece of clean iron or steel. The blade of a penknife will do very well. The iron or steel soon begins to change in appearance, and if you take it out from the solution you will find that instead of looking like iron or steel it now looks like copper. At first you might think that the iron had been changed into copper, but this is not the case. What has happened is that some of the iron has been dissolved and formed iron sulphate, and that some of the copper from the solution has taken the place of the iron. We can describe this change by an equation,

iron + copper sulphate = copper + iron sulphate.

If we took enough iron, all the copper in the solution would be deposited as pure copper, and the blue colour of the copper sulphate solution would change into the greenish colour of iron sulphate. This is a good example of chemical change.

EXPERIMENT 51.—To find out what happens when crystals of salt and crystals of sugar are heated.

Take a few crystals of salt in a dry test-tube and heat them, at first gently and then more strongly. You will notice that the crystals break up with a slight crackling sound, and that a white powder is left behind. Cool the tube and shake out the white powder. Taste it, and compare it with ordinary powdered salt.

In another tube place a few crystals of sugar, and heat these as in the last experiment. Record your observations on the effects of heating salt and sugar. In which case has chemical change taken place?

EXERCISE 9.

Find out whether chemical change takes place when the following substances are heated: sulphate of iron, oxide of mercury, lime, sand.

Give reasons for your opinion in each case.

ANSWERS TO EXERCISES.

Exercise 1.

1—207·7° F.; 181·4° F.; 59° F.; 23° F.

2—21·7° C.; 20° C.; − 17·8° C.; − 40° C.

3—35° C.; 290° C.; 357° C.; 338° C.; 80° C.

4—1832° F.; 1952·6° F.; 2192° F.; 446° F.; 779° F.

Exercise 2.

1—47·14 sq. cm. **2**—400 holes. **3**—The 6-in. pipe. **4**—346·9 sq. yd. **5**—162·8 sq. cm.; 95 sq. cm.; 72·3 sq. cm.

Exercise 3.

1—2262·0 c.c. **2**—391 c.c. **3**—Equal. **4**—31·8 c.c. **5**—264·4 c.c. **6**—24·88 cm. **7**—25·48 cm.

Exercise 4.

1—59·6 c.c. **2**—94·2 cu. ft. **3**—791·1 cu. ft. **4**—58·9 cu. ft. **5**—696·8 cu. in.; 46·4 cu. in. **6**—24·420 cu. ft. **7**—630 balls.

Exercise 5.

1—1·02; 11·4; 8·8; 7·2. **2**—0·57. **3**—11·4. **4**—2·5. **5**—7·13 c.c. **6**—341·2 gm. **7**—497 shot.

Exercise 6.

1—380·6 gm. **2**—8·56 tons. **3**—28 c.c. **4**—3·22 tons. **5**—244·2 gm. **6**—70·4 gm.; 70·4 c.c. **7**—(*a*) 95 gm.; (*b*) 24·7 gm. **8**—11·65 c.c. **9**—14,336 cu. ft. **10**—8·64 cm. **11**—0·75. **12**—0·92.

Exercise 7.

1—6. **2**—8·8. **3**—49·59 gm. **4**—1·6 c.c. **5**—8·75 c.c.; 2·86 gm. per sq. cm.; 1·24 gm. per sq. cm.

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